

NON-SPECIFIC FACTORS IN THE EPIDEMIOLOGY OF YAWS

KENNETH R. HILL, M.D.

*Professor of Pathology,
University College of the West Indies, Jamaica
Formerly Consultant, Treponematoses Control Project in Indonesia,
World Health Organization*

Any infection implies the interplay of three factors : the host, the environment, and the parasite; and epidemiology, which is strictly the study of epidemics, also involves the interplay of those factors within a community. The specific factor in the epidemiology of yaws, I take to be the etiological or causative agent, the *Treponema pertenue*. It is probable that the host and environment have a direct part to play on this treponeme, producing such changes as mutation, variation, and adaptability. These changes may or may not be the cause of certain differences in the clinical manifestations of yaws found from time to time or from place to place, or even may or may not be the cause of the differences between the various treponematoses, such as syphilis, yaws, bejel, pinta, etc. In this paper, however, I will not discuss such controversial subjects but will confine myself to a discussion of the various factors involving the host and his environment. These I consider to be the non-specific factors in the epidemiology of yaws; such factors may alter the incidence and appearance of the disease but are not its cause.

Geographical Distribution

The countries in which the disease is prevalent in South America are the Guianas, Venezuela, Bolivia, Colombia, and most of Brazil. In Central America, the disease is present in Guatemala, Honduras, Costa Rica, and Panama, although the incidence there is low; but in the West Indian islands—Jamaica, Haiti, Trinidad, and the others—yaws is common.

Passing to Africa, one finds the disease very prevalent on the west coast, and in Uganda, Kenya, Tanganyika, and Madagascar. In Asia it is found in the Indian districts of Bengal and Travancore and in Assam, Burma, and Ceylon. It is very common in Thailand and Indo-China, and is also found in southern China and Taiwan (Formosa). The disease

is common in the Malay archipelago and in the Indonesian territories. Finally, it is found in the north of Australia and in the islands of the South Pacific—Fiji, New Hebrides, etc.

Temperature and Altitude

From this survey it would appear that yaws flourishes best in countries which lie approximately within the tropics about the mean annual isotherm of 80°F (27°C) and over. Although yaws may flourish in countries lying between isotherms of 70°F and 79°F (21°C and 26°C), the reported incidence there is definitely lower than around the isotherm 80°F. In Mexico, Cuba, Ecuador, Peru, and Chile, the reported incidence is low. There are, however, areas in which the temperature varies between 79°F and 90°F (26°C and 32°C) and yet yaws is very common—for example, Madagascar, Burma, and Assam—but these places, possibly because of their proximity to the sea, have little fluctuation in their mean annual temperature, and furthermore they have, as I will mention later, a heavy annual rainfall.

In Burma and Assam the incidence is highest in those sections which are towards the 80°F isotherm. Thus Jolly¹⁴ reports that in Burma the disease is mainly confined to the country west of the Irrawaddy; this country is nearest the sea and approaches the 80°F isotherm. In lower Burma the disease is infrequent in the delta region but common along the Tenasserim coast, which is within that isotherm. He states that the same conditions apply in Assam and that yaws is most prevalent in that part of the Lower Chindwin area which is towards the 80°F isotherm.

The disease apparently does not thrive in colder climates or in climates where there are extremes of temperature. There was ample opportunity for it to be carried from the tropics to more temperate climes during the first, and especially the second, World War, and yet the few cases which were reported did not give rise to any known infectivity and were soon cured.

Maxwell²² states that yaws is continually being imported into northern China, but that it soon dies out since it cannot exist outside the tropics, even when unhygienic conditions favour its development.

Historically, it is more than probable that yaws was carried from the west coast of Africa to the New World by the slave trade. It is significant that yaws is endemic in those areas which lie between the two tropics and yet the disease has not taken hold in North America. Cady & Engman in 1924 (quoted by Chambers⁵) found only 51 cases of yaws in the American literature and although their study embraced the southern States of the USA, most of the cases appeared to have been imported.

If temperature is a factor then altitude would be expected to play a part in the epidemiology of the disease, although Castellani & Chalmers³

stated that yaws did not occur in the mountains or at a higher level than 800 feet (250 m). Ramsay,³⁰ on the contrary, has found that yaws is more prevalent in the hills of Cachar, Assam, at heights of 1,000-5,000 feet (300-1,500 m) above sea level than on the plains of that district.

There are districts in Jamaica where the altitude is 1,800-2,300 feet (550-700 m) above sea level and where, according to Chambers,⁵ the incidence of yaws was 57% of the population. Oho²⁵ has reported on an area of yaws infection in the southern tip of the island of Formosa at an altitude of 5,000 feet (1,500 m).

There are several reports that a lower temperature will alter the character and distribution of the yaws lesions. In the Cachar district of Assam, the average summer temperature is 83°F (28°C) and the average winter temperature is 65°F (18°C); the mean average rainfall is 100 inches (260 cm). Ramsay³⁰ states that on the plains in the summer the lesions are of the typical florid variety, but that during the winter months it is a very rare occurrence to see framboesial patients presenting typical yellow-encrusted excrescences; in the latter season, what are usually seen are condylomatous lesions in the warm, moist regions of the axilla and between the nates, chronic dermatitis of the hand, desquamating lesions, with a worm-eaten appearance, of the soles of the feet, and occasional painful joints—all liable to be mistaken as syphilitic. As soon as the weather becomes warmer the characteristic yellow-encrusted yaws may reappear with, on the advent of the rainy season, the painful plantar lesion. Ramsay goes on to say that the same is true in the hills where the cases are atypical yaws. When the patients come down to the plains to reside, the lesions become typical of florid yaws. He states that the cooler the climate, the more yaws resembles syphilis.

Further, Ramsay notes that the incidence of tertiary lesions is much higher in the cooler hills than in the warmer plains. Climate does not explain this, and he attributes it to a possible cross-immunizing effect by the malaria which is much more prevalent in the plains.

Lopez Rizal & Sellards¹⁹ reported that yaws was widespread in Luzon, Philippines. In the areas which had an altitude of 600-2,100 m (approximately 1,950-7,000 feet), the lesions were confined to the mucocutaneous junctions at the mouth, nose, anus, and genitalia. The point here is that it is perhaps due to the colder atmosphere that the treponeme of yaws can find a footing only in these warm, moist areas of the body. This viewpoint has been taken up by Hudson,¹² and although I do not, in this paper, wish to enter into any controversial argument as to whether syphilis and yaws are the same disease or two distinct diseases, there is some evidence that treponematoses is prevalent in a non-venereal form as yaws in the tropics, whereas in colder climates it may change its form and be nurtured, as it were, by the warmer and moist conditions of mucocutaneous sites of infection and, perhaps, by venereal transmission.

Rainfall

The high incidence of yaws within the tropics appears to be intimately bound to a heavy rainfall. If we consider a map of the world giving the annual rainfall, it will be seen that, in general, the heavy incidence of yaws corresponds with those areas where the rainfall is more than 50 inches (1,300 mm).¹² It will be remembered that the incidence on the west coast of South America and in the Sahara Desert, Africa, is either nil or very small; this corresponds to a low annual rainfall.

It is interesting to compare the rainfall map of India with one showing the distribution of yaws. No yaws cases, or very few, are reported from the former Central Provinces or from Hyderabad, Madras, or Mysore, whereas the incidence in Bengal, Assam, and Burma, which are almost in the same latitude, is very high. This is because the former are dry areas in the wake of the summer monsoons which proceed in a north-westerly direction towards the latter, where the rainfall is heavy.

It is well known that there is an increase in the number of cases of yaws during the rainy seasons; this is made up of an increase in new cases or reinfections and of a higher relapse-rate of old cases.

Further, Saunders et al.³³ in Jamaica reported striking differences in the lesions during the wet and dry seasons. In the rainy season a greater proportion of cases showed an open infectious type of lesion, and the papillomatous framboesides tended to be larger, more numerous, and florid. During the dry season, they noticed that the papillomatous framboesides appeared to be localized more in the warm, moist parts of the body, and the early eruptions were frequently of the dry, scaly, maculopapular type. These differences were so striking that Kumm who was working on *Hippelates pallipes*, and who required moist papillomatous framboesides, always chose to work with the treatment team operating in a rainy district. The increase in the number of papillomatous framboesides is illustrated by the following data, taken from Saunders et al.,³³ which show the average monthly rainfall, in inches, for a 3-month period in 10 treatment-areas and the percentage of persons with papillomatous framboesides among the total number of persons who had had yaws for less than 5 years :

Area	Average monthly rainfall (inches)	Total cases of yaws	Papillomatous framboesides (%)
1	2.05	284	7.8
2	5.08	487	17.6
3	6.65	333	17.7
4	7.07	250	15.2
5	9.17	344	29.2
6	10.90	392	31.0

<i>Area</i>	<i>Average monthly rainfall (inches)</i>	<i>Total cases of yaws</i>	<i>Papillomatous framboesides (%)</i>
7	15.41	314	22.3
8	21.51	317	30.9
9	27.09	409	37.7
10	40.49	342	33.9

This increase is well known to the people of Jamaica, and in Indonesia there is a saying that the incidence of plantar lesions is increased "when the bamboo shoots come out", i.e., during the rainy season (R. Kodijat—personal communication, 1950).

I will return to the discussion of the relation of heavy rainfall to the incidence of yaws in a locality later, when I discuss humidity.

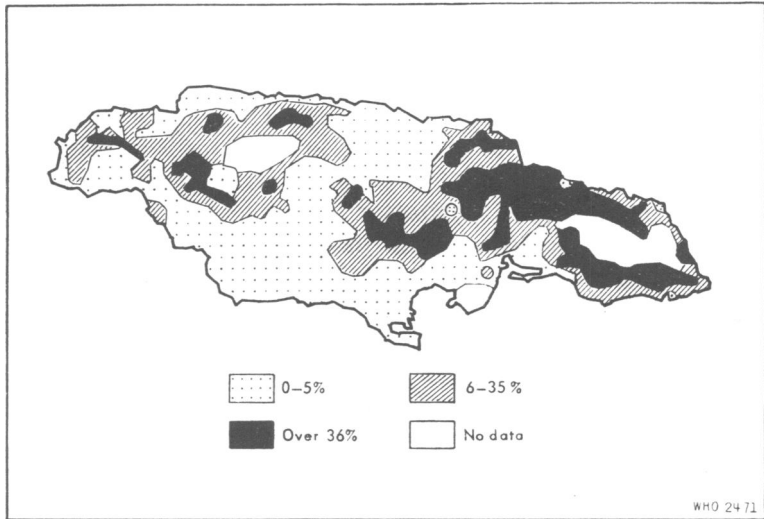
Fig. 1 shows the distribution of yaws in Jamaica and fig. 2, the average annual rainfall; it will be seen that, in general, areas showing a high prevalence of the disease correspond to the areas of heavy rainfall, and that where there is little rainfall there is never any high incidence of the disease.

Geological Formation

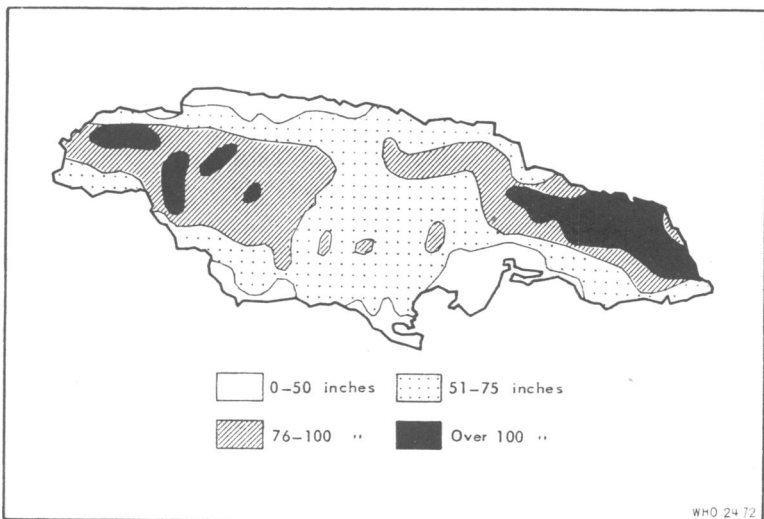
Although the disease is prevalent in rainy districts, it should be noted that a heavy rainfall in the tropics does not necessarily mean a high incidence of yaws. For example, Chambers⁵ reports on three districts in Jamaica, separated from each other by only a few miles; the relevant data on each district are as follows :

<i>District</i>	<i>Altitude (feet)</i>	<i>Rainfall (inches)</i>	<i>Yaws incidence</i>	<i>Soil characteristics</i>
Duncans	300	80	nil	well drained limestone no tenacious topsoil
Duanvale	800	51	high	swampy limestone marly alluvium (holds water)
Devon	2,500	73	nil	well drained limestone no tenacious topsoil

The prevalence of yaws in Duanvale, then, appears to be due to the fact that the water is unable to drain away owing to the marly alluvium; in the other two districts the topsoils are sandy and the water is able to seep away through the limestone. In general, the dampness of the soil will be increased when the soil is impervious, when the drainage is poor, when there is seepage from watersheds and a persistent high subsoil water-level, and when evaporation is limited, as is the case in sun-starved valleys or in areas of dense foliage.

FIG. 1. DISTRIBUTION OF YAWS IN JAMAICA *

* From Saunders et al. ³⁴ (by permission of the editors of the *American Journal of Hygiene*)

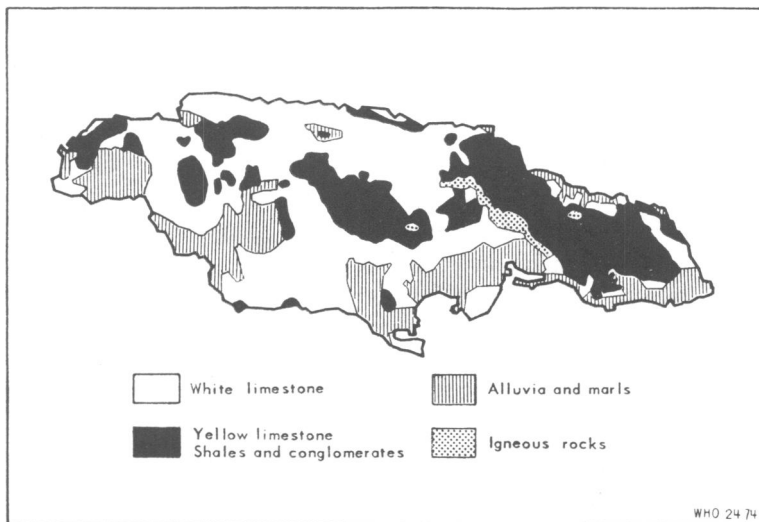
FIG. 2. AVERAGE ANNUAL RAINFALL IN JAMAICA *

* From Saunders et al. ³⁴ (by permission of the editors of the *American Journal of Hygiene*)

Fig. 3 shows the various geological formations in Jamaica, and a comparison with fig. 1, which shows the distribution of yaws, demonstrates a marked correlation between the heavier geological formation in Jamaica and the incidence of yaws.

One noticeable feature is that yaws is least prevalent in areas where white limestone is present; such areas have scanty soil, are pervious to water, and have sparse vegetation. Only in one or two places in the white-limestone areas is there any high incidence of yaws, and in these cases either the limestone has been cut through to an underlying impervious stratum or there is an abundant topsoil.

FIG. 3. GEOLOGICAL FORMATION OF JAMAICA *



* From Saunders et al. ** (by permission of the editors of the *American Journal of Hygiene*)

The formation indicated in fig. 3 as yellow limestone, conglomerates, and shales is not very pervious and supports a luxurious vegetation. The alluvial soils and marls represent fertile deposits; these, although less impervious to water than the yellow limestone, conglomerates, and shales, hold moisture better than white limestone, and show and support a luxurious vegetation. Both types of formation supporting a luxurious vegetation show a high incidence of yaws.

Thus, then, it is evident that yaws is prevalent in areas with a high rainfall, except where there is a pervious limestone formation, and also—this follows from the geological formation of the topsoil—where there is ample vegetation.

Humidity

From the foregoing observations, it can be seen that the three last-mentioned factors affecting the incidence of yaws, namely, rainfall, geological formation, and vegetation, may be crystallized into a single factor—moisture content or humidity.

An example of this is given by Chambers⁵ who describes two districts with the same elevation, rainfall, soil, seepage from watersheds, and standard of living and in which there was a high incidence of yaws. However, in the one which had mountains to the east and west cutting off the hours of sunshine in the morning and evening, the incidence of yaws was about 76%, whereas in the other district the mountains did not interfere with the direct sunshine and the incidence of yaws was about 60%. Chambers attributes the difference in incidence to the difference in humidity in the two places.

Much speculation has arisen with regard to the association of the high humidity of an area with a high incidence of yaws, and there is a tendency to explain it as a case of cause and effect.

It has been said that the treponeme has a relatively longer viability in damp soil and that infection could therefore take place from the “droppings” from sores. Harrison⁹ claims that *Treponema pallidum* can survive, i.e., remain motile, outside the body for as long as two months provided they are kept moist. Against this is the generally accepted theory of the fragility of *T. pertenue*. Yawuyama⁴⁴ has shown that *T. pertenue* has survived outside the body at 28°F (−2°C) for only 30 minutes in saline and for two hours in human serum. Chambers⁵ has observed motility of *T. pertenue* at room temperature—84°F (29°C)—in serum for 8 hours. Furthermore, the fact that very few cases of initial lesions occur on the soles of the feet rather precludes the possibility of infection from droppings. In passing, it may be mentioned that investigations into the pH of the soil in Jamaica have shown no correlation of pH with the incidence of yaws.⁵

A high moisture content or humidity is responsible for a sogginess of the skin and an increase in the incidence of skin infections from fungi and other organisms. Such infections interfere with the integrity of the skin surface, either directly or indirectly due to scratching, so that it would be possible for a treponeme placed in the skin to gain ingress and to cause a yaws infection.

A further explanation commends itself. It is well known that the incidence of plantar yaws increases during the wet season. This is due not to initial infection in the plantar region but rather to re-exacerbation of the disease there. Such lesions (ulcerative plantar framboesides) are infectious and will be a source of new infection to non-immune persons.

Why there should be exacerbation of the disease is unknown; it has been suggested that the sole becomes soggy and that treponemes lying dormant in the tips of the papillae and in the epidermis are stimulated to produce active lesions. This is of importance as it may be the source of the continuation of infection in the community.

At this point, it may be as well to digress and study the course of the disease in a patient. After the initial infection, the patient shows various manifestations of the disease for many years afterwards; such manifestations are usually described as the secondary and tertiary stages of the disease. These waxing and waning recrudescences of the disease generally cease to be infectious within 2 or 3 years, and certainly not more than 4 years, after the initial infection. By "infectious" I mean that treponemes can be demonstrated in the matter from the lesions by means of the darkfield microscope. Later outbreaks are non-infectious except for one type of lesion, the ulcerative plantar lesion or crab yaw, which may appear many years after the initial infection.

An example of this is given by Chambers,⁵ who is a supporter of the theory that the plantar lesion is a potent source of reinfection in a community. A series of 682 patients with lesions (249 infectious and 433 non-infectious) was kept under observation for a period of about two-and-a-half years. At the end of that period there were 70 cases with relapsing lesions—62 non-infectious and 8 infectious. The 8 infectious lesions were all ulcerative plantar lesions.

From this example and many others studied by him, Chambers believes that infectious lesions, other than plantar or palmar, represent a definite stage in the course of the disease and seem to recur but rarely when the maximum time for that stage has been passed. On the other hand, plantar and palmar lesions follow a less clearly defined course and occur many years after the first attack, often concurrently with the so-called tertiary and non-infectious stage of the disease. The principal factor in the production of plantar lesions appears to be a soggy condition of the sole which transforms a dormant organism into an active one. Such soggy conditions of the plantar surfaces and re-exacerbation of the disease are found in hot, damp climates and may explain the continuation of the infection within the community generally as well as the increased incidence during the rainy season. I will return to this aspect later.

That humidity is a factor is illustrated by an example from a publication by Scott,³⁷ who describes an outbreak of yaws among adult labourers in one of the Johannesburg mines; surface workers were not affected, and the majority of those who were affected belonged to one shaft. This shaft was 1,000-2,000 feet (300-600 m) below sea level and the dry-bulb thermometer varied between 88°F and 92°F (31°-33°C). Primary lesions were seen on every part of the body except the feet and ankles; all the men wore boots. Johannesburg (26°S.) is at an altitude of 6,000 feet (1,800 m).

Economic Status and Sanitary Conditions

Before turning to a discussion of the actual mode of infection it will be as well to discuss the economic circumstances and sanitary conditions of the people affected by yaws.

Yaws appears to be endemic where the standard of living is low, and where there is overcrowding and lack of proper sanitation and facilities for personal hygiene; these circumstances are the same for any contagious disease. Turner & Saunders⁴³ have found that yaws in Jamaica is more prevalent among the lower classes of society than among the higher, and Saunders et al.³⁴ have shown that yaws incidence increases as the sanitary status of the home decreases. However, yaws is not always present in communities where sanitary conditions are poor, and from this we must conclude that sanitation and hygiene are not the only factors in the causation of the disease.

It has been shown⁴³ that yaws is a rural disease rarely found in urban areas. Saunders et al.³⁴ studied two districts for incidence of yaws in urban and rural areas. The incidence of yaws in the age-group 10-14 years was about 50% in the country areas and 26% in the town areas, although the standards of sanitation and hygiene were about the same. These authors conclude that the difference in incidence may be due to the fact that in the country there are extensive areas of vegetation (bush), which (*a*) increase the chances of injury to legs and feet and therefore of liability to infection, and (*b*) prevent drying, thereby increasing the humidity.

Another factor which may be relevant is that town people in general wear shoes much more than country people and are better clothed. An interesting example of the protective effect of footwear was given in Burma when the Eighth West African Division retreated from the Arakan in 1944. The soldiers during the retreat found their boots too heavy, so they threw them away; the monsoons were starting and an epidemic of foot-yaws ensued.⁷ In a personal communication (1952), Findlay states that 60% of the cases were of the crab-yaw variety (ulcerative plantar framboeside).

It is evident that yaws declines with the rise of socio-economic status, as judged by Western standards—that is to say, when more clothing and footwear are worn, when standards of personal hygiene and sanitation are more rigorous, and when houses have covered floors and communications are paved.

Diet

The connexion between dietary deficiency and yaws-incidence is not apparent. It is known that dietary deficiencies such as low protein-intake and avitaminosis are common in the tropics, but whether or not a dietary

deficiency makes a patient more prone to yaws infection is unknown. In investigations of a total child population of 280 children under the age of puberty in a village in the Gold Coast, Findlay ⁷ found that only 3.8 % of the 233 children without signs of yaws had evidence of avitaminosis, whereas 14.8 % of the 47 children showing lesions of yaws had marked signs of food deficiency.

Chambers ⁵ brings out the fact that in general the inhabitants of areas in which yaws is endemic are underfed; he points out, however, that inhabitants in such areas are better off agriculturally than are the inhabitants in the "rain-starved" areas, where both yaws and agriculture are limited because of the poor rainfall and pervious soils. Bloss ¹ has stated that yaws is more common among the pastoral Nilotic tribes of the Anglo-Egyptian Sudan than among the agrarian Zande. The former can be regarded as "blood and milk" eaters whereas the latter are vegetarians. He suggests that the difference in the incidence of yaws may be due to diet; but there are several other factors at play in two such widely different groups.

Race

Spittel ³⁹ has stated that yaws hardly ever attacks the European or, for that matter, any cleanly living individual, whatever his race; however, da Silva Araujo ³⁸ gives the following figures for the northeastern province of Brazil: out of 30,000 cases of yaws in a population of one-and-a-quarter million, negroes formed 15.2 %, half-castes 56.2 %, Indians 10.2 %, and "whites" 18.4 %.

There appears to be no racial immunity to the disease, and, given the same circumstances, such as poverty and unhygienic and insanitary surroundings, any racial type will be affected in an endemic area. It would be as well to add, however, that Hewer ¹¹ found syphilis among the inhabitants of northern Sudan and yaws in the southern part of that area; the difference in clinical types he attributed to race, although climatic factors could not be excluded.

Sex

There appear to be rather more males than females who acquire the disease. Chambers ⁵ states that in one series of 641 cases seen with primary lesions, 372 were males and 269 females. The majority of these cases were between 5 and 14 years of age, and the explanation given is that boys are much more active than girls and therefore suffer more traumata; further, girls of school age are usually better clothed than boys of the same age, and this is possibly a protective factor which would tend to reduce the incidence of yaws in the female.

In Jamaica, it is only during the ages of 20 to 29 years that female cases preponderate to the extent of 5 : 3, according to Chambers.⁵ The ages of 20 to 29 years correspond to the period of greatest child-bearing and therefore of the most frequent handling of children, so that the opportunities of acquiring the disease are increased. Findlay⁷ confirms these findings in West Africa. Table I gives the sex distribution of yaws, according to age-groups, in the Bath area, Jamaica, as found by Turner & Saunders.⁴³

TABLE I. DISTRIBUTION OF YAWS ACCORDING TO SEX AMONG SUCCESSIVE AGE-GROUPS IN THE BATH AREA, JAMAICA *

Age-group (years)	Sex	Number of persons	Cases of yaws	
			number	%
Under 5	Male	164	41	25.0
	Female	168	47	28.0
5 - 9	Male	165	99	60.0
	Female	176	91	51.7
10 - 14	Male	134	111	82.8
	Female	156	107	68.6
15 - 19	Male	123	95	77.2
	Female	114	79	69.3
20 - 29	Male	263	190	72.2
	Female	258	154	59.7
30 - 39	Male	187	113	60.4
	Female	183	108	59.0
40 - 49	Male	116	71	61.2
	Female	105	52	49.5
50 - 59	Male	70	38	54.3
	Female	68	32	47.1
60 and over	Male	58	40	69.0
	Female	60	28	46.7
Total	Male	1,280	798	62.3
	Female	1,288	698	54.2

* From Turner & Saunders⁴³ (by permission of the editors of the *American Journal of Hygiene*)

It will be seen that males preponderate at almost all ages, although the incidence tends to be approximately equal among males and females under 5 years of age and between 30 and 40.

Age

The incidence of yaws in relation to the age-groups in the community can be studied under two headings : (1) the age at onset of the disease, and (2) the total number of cases giving a history of yaws, classified according to age.

As regards the age at onset, Chambers,⁵ in Jamaica, found that the incidence of primary lesions reached its peak between the ages of 5 and 9 years, with the next most frequent incidence between the ages of 6 months and 4 years. Out of 580 cases with primary lesions, only 2 were found below the age of 6 months, and those were 4 and 5 months old respectively.

TABLE II. AGE AT ONSET OF YAWS IN BATH AND SEAFORTH AREAS, JAMAICA *

Age at onset (years)	Bath area		Seaforth area	
	number	%	number	%
Under 5	479	35.3	147	27.6
5 - 9	549	40.5	254	47.5
10 - 14	213	15.7	85	15.9
15 - 19	59	4.4	32	6.0
20 - 29	38	2.8	11	2.0
30 - 39	12	0.9	3	0.6
40 - 49	6	0.4	2	0.4
50 and over	0	—	0	—
Total	1,356	100.0	534	100.0

* From Turner & Saunders ⁴³ (by permission of the editors of the *American Journal of Hygiene*)

Turner & Saunders ⁴³ also studied the disease in Jamaica and found in investigating the histories of about 2,000 patients that the greatest number became infected for the first time in the second 5-year period of life, and that 90% of them were infected before the age of 15 years. Less than 5% gave a history of having acquired yaws for the first time after the age of 20. Turner & Saunders' figures are given in table II.

Findlay,⁷ reporting from West Africa, put the peak incidence at between 2 and 5 years of age with a gradual decline towards puberty. He states that yaws is rare before the age of 18 months.

To sum up, most observers find the peak age-incidence of the initial infection to be in the years during childhood up to puberty. These years are, of course, the years of greatest activity and consequently of the greatest injury to the skin.

I shall leave discussion of the total number of cases giving a history of yaws, within a community classified according to age-groups, until we come to the question of immunity.

Site of Infection

The commonest site for the initial lesion is the lower leg, and this corresponds to the site of the greatest frequency of traumata for inhabitants in the country districts. As has just been mentioned, children are the most affected and they constitute the age-groups which are not so well clothed and, in play, sustain injuries to the lower limbs.

According to Chambers,⁵ in a survey of over 2,000 cases, the commonest site of infection was the feet and ankles (infection on the sole was very rare), and the next commonest was the legs and knees. About 75% of all cases were infected on the legs below the knee. The third place in order of frequency was the head and neck, and the fourth, the thighs and buttocks. Less than 3% of the initial lesions were found on the genitalia. Moss & Bigelow,²³ in histories obtained from 968 cases, found that the ankles were the commonest site for the initial lesion, and Turner & Saunders⁴³ found the location of the initial lesion in 1,096 cases to be as follows :

Legs and feet	75.5%
Head and face	12.5%
Upper extremity	7.0%
Thighs and buttocks	4.0%
Genitalia	0.8%
Other locations	0.2%

On the Gold Coast, however, it was found that out of 100 consecutive cases investigated, the initial lesion was on the buttocks, perineum, and thighs in no fewer than 57 cases.⁷ This was attributed to the fact that the parts of the body in contact with the ground when the patient is sitting are the areas most commonly affected.

Mode of Infection

Now let us turn to the consideration of the modes of infection; these may be listed as follows :

- (1) by contact between humans;
- (2) by an insect vector;
- (3) by congenital acquisition;
- (4) by other sources.

Contact

It is almost universally considered that the commonest mode of infection is by contact between individuals. The actual mode of infection is the depositing of the treponeme, contained in the pus from open sores, on to the skin of a non-immune person so that the treponeme gains ingress and sets up a new infection. In support of this theory of contagion is the fact that the peak age for the initial acquisition of the disease is the years of childhood before puberty, when, as is to be expected, children in play come together without regard for the niceties of sophisticated behaviour and when, as a consequence of violent activities, breaches in the skin from injury are to be expected much more frequently than in higher age-groups. In addition, children, in whom the disease is commonest, are more scantily clad and do not wear shoes as frequently as their elders.

The theory of the contagious nature of the disease, by infection through abrasion, is also supported by the fact that the disease is commonest in the country districts where vegetation (bush) would tend to produce minute abrasions on unclothed legs and unshod feet, especially when the latter are associated with a soggy skin—the inevitable result of working in such damp areas.

There is little evidence that yaws is transmitted venereally. The disease primarily attacks young children, and the incidence of penile primary lesions is variously stated to be about 3% (Chambers⁵) and less than 1% (Turner & Saunders⁴³).

The fact that yaws is rarely found in urban communities, possibly because the paving of streets and the wearing of clothes—a necessity for conformity to the social pattern—both tend to prevent abrasion of the skin, supports the argument for the contagious nature of yaws.

Whether or not infection can take place through intact skin is a debatable point. There is always the possibility, which still remains unproven, that treponemes, themselves microscopic in size, may gain access through injuries of microscopic size. However, many experiments have been carried out in humans where the disease has been transmitted by direct contact when there has been a trauma of some sort.^{26, 36}

Insect vectors

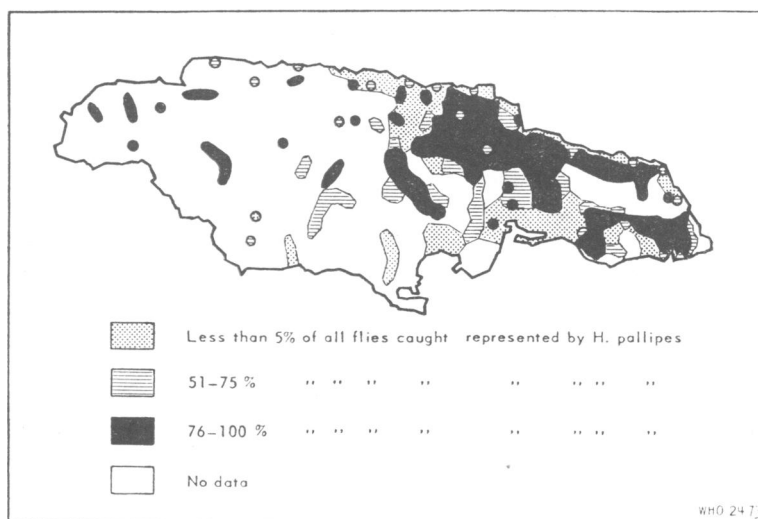
The transmission of yaws by flies has been suggested by several authors. Robertson,³² in the Gilbert and Ellis Islands, has studied the problem of

flies as carriers of yaws; he caught 200 flies which were feeding on yaws lesions, washed them in sterile water, and found the *Spirochaetae pertenuis* of Castellani in smears from centrifuged deposits of the washings. From this he concluded that flies are potential carriers of the disease; unfortunately he does not specify in his article the type of fly which he studied.

Thomson & Lamborn⁴¹ in Africa have shown that *T. pertenuis* can pass through *Musca spectanda* which have fed on yaws sores and be deposited in the dejecta, which may, therefore, potentially infect any breach of the skin.

Perhaps the best researches are those of Kumm and his colleagues,^{15,16,17,18} who have studied the transmission of yaws from man to rabbits by the

FIG. 4. DISTRIBUTION OF HIPPELATES PALLIPES IN AREAS SURVEYED FOR FLIES IN JAMAICA *



* From Saunders et al.³⁴ (by permission of the editors of the *American Journal of Hygiene*)

insect vector, *Hippelates pallipes* Loew. These workers have shown that *H. pallipes* feeds on yaws lesions in enormous numbers; for instance, 673 flies were caught in 15 minutes from one ulcer on a boy's leg. If the lesion is covered by a scab, the flies crawl under the scab through any cracks and holes that may be available; I have observed this myself. It has been demonstrated on dissection that, after feeding, the fly contains many treponemes; for example, 304 *T. pertenuis* were found after one minute, 138 after 6 hours, and 15 after 18 hours. The treponemes have been shown to remain motile up to 7-8 hours in the oesophageal diverticulum and may be regurgitated in the vomit drop. Further, Kumm & Turner¹⁷ have shown that after *H. pallipes* has fed on a human case, its vomit drop, containing treponemes, has transmitted the disease to rabbits.

These authors also point out that *H. pallipes* has a decided preference for feeding on the lower extremities; and that the degree of correlation between the distribution of *H. pallipes* in Jamaica and that of yaws is most striking, both being most prevalent where there is a high rainfall throughout the year and a luxuriant vegetation (see fig. 4). However, it should be noted that *H. pallipes* is also common in some localities which have a dense jungle-type of vegetation and high rainfall but no yaws.

Saunders et al.³⁴ state : " We cannot yet decide whether the distribution of *Hippelates pallipes* in Jamaica determines the distribution of yaws or whether both are affected by the same environmental factors causing their distribution to coincide ". And that is the position today.

Congenital infection

It is the consensus of opinion that yaws is not acquired congenitally. Chambers,⁵ in a total of 8,000 histories, came across no evidence of congenital lesions or stigmata of yaws. Suckling infants in the first year of life are seldom affected by yaws and this may be due to the fact that such children are not subjected to trauma as older children are, and therefore the treponemes would not gain ingress into the skin. Further, I have seen many *H. pallipes* surrounding the eyes of children in homes where yaws is active, but have only occasionally seen yaws infection of the eye. In my experience, the majority of suckling infants affected with yaws have shown their initial lesions in the peroral and oral region.

Another reason why newly born infants are apparently unaffected is that they may have some transmitted immunity. However, Chambers⁵ reports that the serological tests on six infants born to mothers who had received no form of treatment for relapsing yaws lesions during the period of gestation were negative. In another case,⁴ the mother became infected during the later months of her pregnancy, and the disease was active during and after the birth of the child; nevertheless, the child showed no stigmata or signs of yaws and the serological tests were normal.

Mattlet²¹ also describes a case of a mother with florid yaws who gave birth to a child with a negative serological titre, and Baermann (quoted by Hermans¹⁰) found two similar cases in which the child had a negative titre.

Admitting that the reagin or complement-fixing antibody is not the immune antibody, it is hard to understand in the above cases from the literature why the reagin did not pass the placental barrier. However, the transmission of reagin from the mother's blood to the baby is a complex problem which is also found in syphilis.⁴⁰ It is known that in some cases of syphilis the mother may have large amounts of reagin which is not transmitted to the baby, whereas in other cases the maternal reagin may be of low titre and yet the child is serologically positive. The reason for this is obscure.

A case which came under my observation may be of interest. A 22-year-old Chinese girl with florid yaws presented herself when she was six months pregnant. Her serological titre was 512 Kahn units, and her initial infection had occurred 3 months previously. She received no treatment and was delivered of a premature child 6 weeks before the estimated term. The child appeared normal and the cord blood had a titre of 32 Kahn units. The placenta seemed normal and was not remarkable histologically; treponemes were not demonstrated. Four months after birth the child still had a positive titre although a quantitative test was not made. There were no stigmata or lesions of yaws. This case is the first I know of in which a positive titre has been reported in an infant delivered from a mother with active yaws; it will be interesting to watch this baby's titre, and to note the possibility of infection or immunity, and/or the development of lesions.

Other sources of infection

Sources of transmission of the disease other than those described are probably rare. Infection from contamination of objects is unlikely because of the fragility of the organism, particularly its low resistance to drying. The possibility of infection from a reservoir in animals is also unlikely, although it cannot be excluded, because the disease has been transmitted, with difficulty, to rabbits, hamsters, monkeys, and, I understand, donkeys (Dr. F. W. Aris—personal communication, 1951).

Natural and Acquired Immunity

It is a widely held belief among many native populations that a childhood infection of yaws prevents, or at least mitigates, an infection in adult life. So deeply is this belief ingrained in local customs that, sometimes, a mother with an uninfected child will take that child to play with an infected one, so that he may acquire the disease and gain protection. I well remember an African who has now attained fame in the Judiciary telling me that he had been taken by his grandmother to a neighbouring village and so infected.

Further, the native often refuses treatment for the disease in the initial stage before the florid, so-called secondary, lesions have had time to appear, or resists efforts to treat this later stage before it has run its normal course.

In Jamaica, at the time of the early and, because uncompleted, somewhat inadequate arsenic treatment for yaws, many cases were cured very quickly and then relapsed; the native population attributed the relapse to the fact that the disease had not run its natural course and produced immunity, and summed it up when the relapse occurred by the saying "him got juk [injection] before the yaws ripe" (L. E. Arnold—personal communication, 1952).

I remember one day at Winneba on the Gold Coast when I had a line of yaws patients in front of me. They were to be injected with penicillin. One mother accompanying a child with beautiful florid yaws refused treatment for her son when she learned what the "pumpies" (injections) were for. The reason for this attitude, she explained, was the belief that if her son had the yaws cured before it had run its course, he would get "the worse disease" later on!

Turner,⁴² working in Jamaica, carried out a series of experiments on the resistance of yaws patients to re-inoculation with yaws treponemes. He found that out of 18 patients, aged from 2 to 11 years, auto-inoculated with treponemes from their own lesions (duration of disease from onset, 1 week to 7 years), only one gave rise to a new lesion. From this he concluded that a resistance to auto-inoculation was set up early in the disease.

However, he inoculated 67 yaws patients with heterologous strains of *T. pertenue* and showed that immunity varied according to the duration of the first infection and that several years had to elapse before resistance to the second infection was attained (see table III).

TABLE III. RESULTS OF RE-INOCULATION OF YAWS PATIENTS WITH HETEROLOGOUS STRAINS OF YAWS TREPONEMES, ACCORDING TO DURATION OF FIRST INFECTION *

Duration of first infection (years)	Number of patients	Results of re-inoculation			
		positive		negative	
		number	%	number	%
< 1	16	12	75.0	4	25.0
1 - 3	14	10	71.5	4	28.5
3 - 8	18	8	44.4	10	55.6
10 - 65	19	3	15.8	16	84.2

* From Turner ⁴² (by permission of the editors of the *American Journal of Hygiene*)

Table IV gives Turner's results of re-inoculation with heterologous strains of yaws treponemes according to the stage of first infection. These results show that, in some cases, the resistance to heterologous infection is present when the active lesions are also present; there appears to be little immunity in the latent stage immediately following treatment. Immunity in the latent stage two years after the active lesions have disappeared as a result of either treatment or spontaneous regression, however, appears to be high.

It will be seen from what follows, however, that there is some epidemiological evidence that immunity may be present in the adult population without the medium of an active childhood infection.

TABLE IV. RESULTS OF RE-INOCULATION OF YAWS PATIENTS WITH HETEROLOGOUS STRAINS OF YAWS TREPONEMES, ACCORDING TO STAGE OF FIRST INFECTION *

Stage of first infection at time of re-inoculation	Number of patients	Results of re-inoculation			
		positive		negative	
		number	%	number	%
Active lesions present	26	11	42.3	15	57.7
Latent owing to recent treatment; active lesions within past year	23	19	82.6	4	17.4
Latent for more than 2 years, owing to spontaneous regression or treatment	18	3	16.7	15	83.3

* From Turner ** (by permission of the editors of the *American Journal of Hygiene*)

The number of people with a past or current history of yaws in a community in Jamaica is shown in table V. From this table it can be seen that in the particular area studied (the Bath area), 58.3% of the total population had had yaws at some time or other. It will be noted that the proportion of infected children rises rapidly with age to reach a peak in the 10-14 years' age-group; from this age-group upwards, the incidence falls, until the 60 years and over group is reached when there is again a slight increase.

TABLE V. HISTORIES OF YAWS, PAST AND CURRENT, AMONG SUCCESSIVE AGE-GROUPS OF THE KNOWN POPULATION OF THE BATH AREA, JAMAICA, 1935 *

Age-group (years)	Number of persons	History of yaws	
		number	%
Under 5	332	88	26.5
5 - 9	341	190	55.7
10 - 14	290	218	75.2
15 - 19	237	174	73.4
20 - 29	521	344	66.0
30 - 39	370	221	59.7
40 - 49	221	123	55.6
50 - 59	138	70	50.7
60 and over	118	68	57.6
Total	2,568	1,496	58.3

* From Turner & Saunders ** (by permission of the editors of the *American Journal of Hygiene*)

Now, why should there be a fall in the rate of persons giving a history of the disease after the age of 10-15 years? There are several reasons which suggest themselves.

(1) In the survey made, many cases with a positive Wassermann reaction but no history of yaws were not included. As there was found to be little syphilis in the district, it is possible that these cases were, in fact, yaws.

(2) It is possible that the death-rate among those previously affected by yaws was higher than among those unaffected. This is unlikely, however, because yaws is never a "killer" and the morbidity from yaws in patients over 40 years old is negligible.

(3) It is possible that there had been a considerable interchange of population; this in fact did not take place, but if the interchange had been from areas with a lower incidence of yaws then, as will be seen later, the attack-rate among non-immune immigrants would have been expected to be higher.

(4) It is possible that the memory of a childhood infection had faded with the advancing years. Further, it is known that the serological and clinical evidence of the disease may disappear with the lapse of time.

(5) It is possible, but unlikely, that the incidence of yaws in the district at the time of the survey was greater than in former years.

(6) It is possible that a natural immunity develops with advancing age.

All these factors may play a part in reducing the incidence of yaws, either past or current, in the adult population.

Now let us look at the problem from another angle, that of the annual total attack-rates in successive age-groups. Table VI shows that the disease is mainly acquired in childhood and that persons are rarely attacked for the first time in adult life. In the Bath area, the attack-rate among all persons under 20 years of age is of the order of 50% whereas among those over 20 it is only about 2%.⁴³

Table VII shows the attack-rates in the various age-groups according to the estimated numbers of non-immune persons, i.e., those giving no history of previous infection. An analysis of this table again shows the striking difference between the incidence of the disease in childhood and that in adult life. The high numbers of non-immune persons over 20 years old should also be noted. It may be concluded from the study of attack-rates that, owing either to a lack of natural immunity or to a greater liability to exposure, children who have never had an attack of yaws are more prone to infection than adults who have never had the disease.

Granted that the number of estimated non-immune persons in adult life may be artificially swollen by the factors mentioned before, namely, influx of non-immune immigrants, poor memory, and fading physical and serological signs, it is obvious that the large numbers of non-immune persons are due mainly to the constant maturation into the adult groups of uninfected, non-immune children. As these children grow older, they

TABLE VI. ANNUAL ATTACK-RATE AMONG ALL PERSONS OF SUCCESSIVE AGE-GROUPS IN BATH AREA, JAMAICA, 1931 AND 1932 *

Age-group (years)	Number of persons	1931		1932	
		number of new infections	attack-rate (per 1,000)	number of new infections	attack-rate (per 1,000)
Under 5	332	24	72	21	63
5 - 9	341	25	73	18	53
10 - 14	290	14	48	12	41
15 - 19	237	4	17	0	0
20 - 29	521	3	6	2	4
30 - 39	370	1	3	0	0
40 and over	477	0	0	0	0
Under 20	1,200	67	55.8	51	42.5
Over 20	1,368	4	2.9	2	1.4
Total	2,568	71	27.7	53	20.6

* From Turner & Saunders ⁴³ (by permission of the editors of the *American Journal of Hygiene*)

TABLE VII. ESTIMATED ANNUAL ATTACK-RATE AMONG NON-IMMUNE PERSONS OF SUCCESSIVE AGE-GROUPS IN BATH AREA, JAMAICA, 1931 AND 1932 *

Age-group (years)	Estimated number of non-immune persons	1931		1932	
		number of new infections	attack-rate (per 1,000)	number of new infections	attack-rate (per 1,000)
Under 5	241	24	100	21	87
5 - 9	142	25	176	18	127
10 - 14	62	14	226	12	193
15 - 19	50	4	80	0	0
20 - 29	120	3	25	2	17
30 - 39	109	1	9	0	0
40 and over	161	0	0	0	0
Under 20	495	67	135	51	103
Over 20	390	4	10	2	5
Total	885	71	80	53	60

* From Turner & Saunders ⁴³ (by permission of the editors of the *American Journal of Hygiene*)

appear to become less susceptible to infection, for table VII clearly shows that the tendency to acquire the disease in adult life is reduced.

An example of the tendency to acquire the disease in childhood and of the rareness of attack for the first time in adult life is given by Powell,²⁷ who observed the spread of yaws in a closed community of 6,000 persons in India over 10 years. In all, he observed the spread of 653 cases and stated that yaws was most common from 2 to 14 years of age. In this case the adult population was static and totally non-immune, yet the adult incidence of the disease was low.

What then are the causes of a reduced attack-rate among adults ? To my mind there are three possible explanations :

(1) Many of the adult population may have had a childhood infection which they have forgotten and which now shows no signs physically or serologically. It is possible that they still retain some immunity although their reagin tests are negative.

(2) Persons in adult life may have acquired a natural immunity.

(3) Because of advancing years, with less activity to produce trauma to the skin and the more staid conformity to an established social behaviour, more clothes are worn, and the exposure to and risks of infection are reduced.

Cross-Immunity with Syphilis

There is a considerable amount of epidemiological evidence indicating that syphilis is rare in regions where yaws is endemic, which suggests that an attack of yaws confers immunity to syphilis; for example, syphilis does not exist among the Polynesians in Fiji, Tonga, and Samoa, whereas the incidence of yaws is high.²⁹

Hackett⁸ described two areas in Uganda separated by 200 miles; in one, Lira, yaws was very prevalent (20.9% of outpatient department attendance; syphilis, 1.1%) with a high childhood incidence of papillomatous lesions and an absence of primary genital lesions in children and adults; in the other area, Masaka, syphilis was prevalent (17.5% of outpatient department attendance; yaws, 1.6%) with a high incidence of primary genital lesions in young adults and an absence of generalized eruptions. He was unable to differentiate tertiary skin lesions of yaws and syphilis clinically. Findlay⁷ states that yaws is uncommon in northern Nigeria but syphilis appears to take its place.

As previously mentioned, Hewer¹¹ found yaws prevalent in southern Sudan and syphilis in northern Sudan with a gradual gradation of the two diseases between these areas. He found a moderate pleocytosis in the cerebrospinal fluid of many cases of classical yaws in the south with no neurological signs, whereas in the north, frank meningovascular syphilis was encountered. Hewer attributed this mainly to a difference in race although climatic factors could not be excluded.

As regards the immunity of the yaws patient to syphilis, the evidence from experiments and accidental infection is equivocal. Charlouis⁶ successfully inoculated a patient who had florid yaws with material obtained from a penile chancre, and produced secondary syphilis; Powell²⁸ has described two cases, and McKenzie²⁰ and Carman² one case each, in which patients with early yaws lesions have acquired syphilis naturally. As Turner⁴² maintains, all these cases were at the stage when inoculation by a heterologous yaws virus would be expected to be successful in about 50% of the cases. I personally remember two cases in the Gold Coast of old latent yaws which were successfully inoculated with *T. pallidum* and produced primary chancres.

As regards the immunity of syphilis patients to yaws, Jahnel & Lange¹³ inoculated 25 patients who had neurosyphilis with *T. pertenue* and obtained a positive result in only one case. Van der Schaar,³⁵ in Java, inoculated 28 neurosyphilis patients with *T. pertenue*, and only one gave a positive result. In 1936, working in Jamaica, Turner⁴² similarly inoculated 10 cases of syphilis with *T. pertenue* and failed to obtain a positive result in any case.

The evidence therefore seems to indicate some cross-immunity between the two diseases; this cross-immunity is most marked in syphilis and in those cases of yaws in which the duration of the active period or of the latency is long. This is explained by the fact that processes activating the immunizing mechanism in syphilis develop much faster than do those in yaws, and, in the latter disease, it is only when such processes have been allowed to run their full, but slow, course that any cross-resistance can be expected.

It is of interest to note that van Nitsen²⁴ stated from observations in the Belgian Congo that no high incidence of syphilis occurred when yaws was greatly reduced. However, the conclusion that this is proof that no cross-immunity exists is open to criticism on the grounds that the reduction of yaws in a community by therapy had not at that time affected the immunity of the adult population who had latent yaws. If there is any truth in the cross-immunity theory, it will be shown later by an increased incidence of syphilis in the next generation of young adults who, having been treated for active yaws as children, have been unable to stimulate an immunity.

Certain Aspects of Treatment

Table VIII shows the age-distribution of cases exhibiting infectious yaws lesions among the total known population of the Bath and Seaforth areas of Jamaica.⁴³

In the Bath area, 90.1% of the patients with infectious lesions were under 20 years of age, while patients with infectious lesions comprised only 16.1% of all persons under 20 years old and only 1.3% of those over that

age. In Seaforth, 93% of the patients with infectious lesions were under 20, whereas the incidence of infectious cases was 6.5% of all persons under 20 and 0.3% of those over 20.

TABLE VIII. AGE DISTRIBUTION OF CASES EXHIBITING INFECTIOUS YAWS LESIONS AMONG THE TOTAL KNOWN POPULATION OF THE BATH AND SEAFORTH AREAS, JAMAICA *

Age-group (years)	Bath area			Seaforth area		
	total number of persons	cases with infectious yaws lesions	proportion of cases to total persons (%)	total number of persons	cases with infectious yaws lesions	proportion of cases to total persons (%)
Under 5	332	61	18.4	218	13	6.0
5 - 9	341	75	22.0	241	23	9.5
10 - 14	290	46	15.9	194	9	4.6
15 - 19	237	12	5.1	165	8	4.8
20 - 29	521	14	2.7	391	3	0.8
30 - 39	370	0	0	301	0	0
40 - 49	221	2	0.9	200	0	0
50 - 59	138	1	0.7	124	1	0.8
60 and over	118	1	0.8	133	0	0
Total	2,568	212	8.3	1,967	57	2.9

* From Turner & Saunders ⁴² (by permission of the editors of the *American Journal of Hygiene*)

It is clear then that the sources of contagion are largely confined to persons in the first two decades of life. Persons under 20 normally comprise about 50% of the Jamaican population and therefore treatment may be simplified, for the number infected in this age-group is less than one-fifth of the total under 20 years old.

From table IX we can see that the attack-rate in the total population has been reduced by treatment from 56.7 per 1,000 to 7.3 and 8.2 per 1,000 within the first and second year respectively, and the attack-rate in the non-immune population from 119.5 per 1,000 to 15.4 per 1,000 in the first year and 17.3 per 1,000 in the second. There appears, however, to be a constant level below which we cannot go with the ordinary treatment methods. If the figures of the Jamaica Yaws Commission ³³ are analysed, it is seen that relapses after arsenic or bismuth treatment are about 14% - 15% one year after treatment and 25% 2 years after (see table X).

This continuation of infectivity within the community may be due to several causes. The most obvious one is relapse in treated cases. It is unfortunate that the figures given by the Jamaica Yaws Commission do not give the age-groups for the relapsing cases or the site of the relapsing lesions.

TABLE IX. ESTIMATED ATTACK-RATES PER 1,000 OF TOTAL POPULATION AND PER 1,000 OF NON-IMMUNE POPULATION FOR ONE YEAR BEFORE TREATMENT AND FOR THE FIRST, SECOND, AND THIRD CONTROL YEARS *

Period	Number of areas	Total population	New infections			Non-immune persons		
			number	attack-rate (per 1,000)	decrease in attack-rate (%)	number	attack-rate (per 1,000)	decrease in attack-rate (%)
Year before treatment	9	21,900	1,243	56.7	0.0	10,405	119.5	0.0
First control year	9	21,900	160	7.3	87.1	10,405	15.4	87.1
Second control year	9	21,900	180	8.2	85.5	10,405	17.3	85.5
Year before treatment ^a	4	9,800	474	48.4	0.0	4,730	100.2	0.0
Third control year	4	9,800	55	5.6	87.4	4,730	11.6	87.4

* From Saunders et al.²² (by permission of the Jamaica Yaws Commission)

^a The figures given here are for the 4 of the 9 areas for which a third control examination was made.

TABLE X. PERCENTAGE AND TYPE OF RELAPSES IN JAMAICA AFTER TREATMENT WITH NEOARSPHENAMINE OR BISMUTH SALICYLATE *

Original diagnosis	Total cases		Type of relapse (%)									
			infectious		non-infectious		all definite relapses		questionable relapses		total relapses	
	A ^a	B ^b	A	B	A	B	A	B	A	B	A	B
during 12 months' observation												
Infectious	637	329	6.8	9.1	7.5	6.4	14.3	15.5	2.2	3.0	16.5	18.5
Non-infectious	766	397	2.4	2.5	11.6	9.3	14.0	11.8	3.7	2.5	17.7	14.3
Latent	377	222	2.1	1.8	6.4	2.7	7.5	4.5	4.0	1.4	11.5	5.9
Total	1,780	948	3.6	4.6	8.6	6.8	12.2	11.4	3.0	2.4	15.2	13.8
during 24 months' observation												
Infectious	341	183	12.6	17.5	15.0	13.1	27.6	30.6	2.1	4.4	29.7	35.0
Non-infectious	384	253	3.7	2.8	20.3	15.0	24.0	17.8	2.9	3.9	26.9	21.7
Latent	217	158	3.7	4.4	10.1	7.6	13.8	12.0	7.8	1.3	21.6	13.3
Total	942	594	6.9	7.7	16.0	12.5	22.9	20.2	7.1	3.3	26.6	23.6

* From Saunders et al.²² (by permission of the Jamaica Yaws Commission)

^a A = treated with neoarsphenamine

^b B = treated with bismuth salicylate

However, their figures do show that treated infectious cases may relapse within the first two years and give a higher percentage of infectious cases than the relapsing latent or non-infectious cases.

It is worthy of note that latent cases also have a fairly high relapse-rate despite treatment. What then of the latent case which is not treated—and this may be quite common? Such cases may well be a potent source of reinfection in the community. The elimination of the relapsed case in any treatment campaign involves a continuation or consolidation phase, as outlined by Reynolds et al.,³¹ which must continue for many years, especially as the relapsing infections (plantar ulcerative lesions) may occur years after the initial infection.

However, the continuation of infectivity within a community may also be due to a migration of infectious cases into the area from outside, although this did not apply to any extent in the Jamaica surveys. Another reason would be the presence of some other reservoir of infection; the evidence available at present does not support this.

I have mentioned that the child population seems to be more susceptible to the disease than the adult and also that there appears to be little immunity to a second infection immediately following the successful treatment of an active, early phase of the disease. It would therefore seem that an immunological approach would be worth considering. Many readers will be familiar with the active and passive immunization against various diseases carried out by Dr. Stokes and his colleagues in Philadelphia. In this method, gamma globulin from the blood of the adult, supposedly previously infected, population is injected during the incubation or active phase of the disease, in diseases such as mumps, whooping cough, or infective hepatitis. An active and passive immunization occurs. Why? No one knows; for, as yet, the method is still in the experimental stage.

In my laboratory we are now working on this method of immunization, injecting globulin from the adult population which has had yaws into the child population with active disease. We propose to inject globulin as the first "shot" in the treatment so as to stimulate immunity, and then at a later date—say two weeks after—cure the patient of the active disease with penicillin. Such methods, if successful, may also produce a cross-immunity to syphilis and prevent reinfections and relapses.

In treatment, therefore, two objectives should be observed for the elimination of yaws:

- (1) Adequate treatment not merely to render infectious cases non-infectious but rather to cure an individual case completely so that it will not relapse. (Active and passive immunization of the child population, if proved successful, should be considered.)
- (2) Follow-up and consolidation of any mass-treatment programme so as to treat any relapsing case when it occurs.

SUMMARY

After briefly reviewing the geographical distribution of yaws, the author considers the relation of temperature, altitude, rainfall, geological formation, and humidity to the incidence of the disease. Yaws flourishes in hot climates near the mean annual isotherm of 80°F, where there is comparatively little fluctuation of temperature, and where there is an annual rainfall of over 50 inches. The number of cases in such areas tends to increase during the rainy seasons, and there may be differences in the type and location of the lesions in different seasons. However, a high rainfall does not necessarily entail a high incidence of yaws.

Investigations in Jamaica seem to show that the incidence of yaws is higher where the soil is impervious and the drainage poor, although other areas with pervious soil may have a higher rainfall. The author considers that all these factors can be merged into the general one of humidity, high humidity being associated with a high incidence of yaws.

The disease is primarily one attacking rural communities, particularly those in poor economic circumstances and with low standards of hygiene, the incidence declining with a rise in social and economic status. There is no conclusive evidence that either dietary deficiency or racial characteristics have any direct effect on incidence, but it appears that rather more males than females suffer from the disease, which is most usually acquired during the first ten years of life. The commonest site of the initial lesion is the lower leg, which corresponds to the site of the greatest frequency of traumata in rural areas. It is generally considered that the most frequent mode of infection is by person-to-person contact, the causative agent—*Treponema pertenue*—being deposited on the skin of a non-immune person

RÉSUMÉ

Après avoir exposé rapidement la répartition géographique du pian, l'auteur étudie l'influence que peuvent exercer sur la fréquence de la maladie la température, l'altitude, les précipitations, la nature du sol et du sous-sol et l'humidité. Le pian est particulièrement répandu dans les régions chaudes proches de l'isotherme annuel moyen de 27°C, où les fluctuations de température sont relativement faibles et où la hauteur pluviométrique annuelle est supérieure à 1.270 mm. On assiste, dans ces régions, à une recrudescence de la maladie aux époques pluvieuses de l'année; d'autre part, la nature et la localisation des lésions peuvent varier avec les saisons. Toutefois, les pluies abondantes ne s'accompagnent pas nécessairement d'une fréquence élevée du pian.

Des enquêtes entreprises à la Jamaïque semblent indiquer que cette affection est plus fréquente dans les régions où le sol est imperméable et l'écoulement des eaux imparfait que dans celles où les chutes de pluie sont plus considérables, mais où le sol est perméable. L'auteur ramène tous les facteurs considérés à la notion générale d'humidité, une forte humidité correspondant à une fréquence élevée du pian.

La maladie frappe surtout les collectivités rurales, notamment celles qui sont pauvres et où l'hygiène laisse à désirer. Sa fréquence diminue lorsque les conditions sociales et économiques s'améliorent. On ne peut affirmer que la race ou le régime alimentaire ait une incidence directe sur la fréquence du pian, mais il semble que cette maladie, qui se contracte généralement au cours des dix premières années de vie, soit un peu plus répandue chez les hommes que chez les femmes. Les lésions initiales apparaissent le plus souvent sur la partie inférieure de la jambe, qui est la région du corps la plus exposée aux blessures dans les zones rurales. On estime communément que le pian se transmet dans la plupart des cas par contacts d'homme à homme : *Treponema pertenue*, l'agent causal, est déposé sur la peau d'un sujet non immun et pénètre

and entering through cuts or abrasions. It is also possible that yaws may be transmitted by insect vectors; in Jamaica, for instance, there is a striking degree of correlation between the distribution of the fly, *Hippelates pallipes*, and that of yaws. However, it is still uncertain whether the one affects the other or whether both are affected by the same environmental factors which cause their distribution to coincide. Children born to mothers infected with yaws are generally unaffected and most of the evidence seems to indicate that the disease is not acquired congenitally.

The author next considers the question of natural and acquired immunity, and points out that many native populations believe that a childhood infection of yaws prevents or mitigates infection in adult life. Experiments made in Jamaica indicate that persons auto-inoculated with treponemes from their own lesions are unlikely to develop new lesions, and that resistance to auto-inoculation is set up early in the course of the disease. However, inoculations with heterologous strains of *T. pertenue* show that several years must elapse before resistance to a second infection is attained. There is also some epidemiological evidence that immunity may exist in adults without their having had an active infection in childhood. Tables giving attack-rates in Jamaica by age-groups show a striking difference between the incidence of yaws in childhood and that in later years. The author suggests three possible explanations for this : (1) many adults may have had and forgotten a childhood infection and may retain some immunity, although their reagin tests are negative; (2) they may have acquired a natural immunity; and (3) they are generally less active and wear more clothes than children, thus reducing the risk of infection.

There is also evidence that syphilis is rare in regions where yaws is endemic—a fact which suggests that there is some cross-immunity between the two diseases. This cross-immunity is most marked in

dans l'organisme par les coupures ou les excoriations. Il se peut aussi que le pian soit transmis par des insectes vecteurs. La distribution géographique de la mouche *Hippelates pallipes* coïncide en effet étrangement avec celle du pian. Il est toutefois encore impossible de préciser si l'un des éléments détermine la présence de l'autre ou si leur coexistence s'explique simplement par le fait que les mêmes conditions régissent leur répartition. Les enfants de mères pianiques naissent généralement indemnes, aussi y a-t-il lieu de croire que le pian n'est pas héréditaire.

L'auteur examine ensuite la question de l'immunité naturelle et de l'immunité acquise. Dans de nombreuses régions, la population croit communément que le pian contracté dans l'enfance prévient ou atténue l'infection à l'âge adulte. Des expériences faites à la Jamaïque indiquent que les personnes inoculées avec des tréponèmes provenant de leurs propres lésions acquièrent rarement de nouvelles lésions et que la résistance à l'auto-inoculation s'installe à un stade précoce de la maladie. Toutefois, des inoculations pratiquées avec des souches hétérologues de *T. pertenue* montrent qu'il faut plusieurs années avant que s'établisse une résistance aux réinfections. D'autre part, certaines données épidémiologiques donnent à penser que les adultes peuvent posséder une immunité sans avoir été atteints de pian évolutif dans leur enfance. En effet, les tableaux indiquant les taux d'infection par groupes d'âge à la Jamaïque font apparaître une différence frappante entre la fréquence du pian chez les enfants et chez les adultes. L'auteur voit à cela trois explications possibles : 1) de nombreux adultes peuvent, sans se rappeler, avoir eu une infection dans leur enfance et avoir conservé une certaine immunité bien que les épreuves sérologiques soient négatives; 2) ils peuvent avoir acquis une immunité naturelle; 3) étant généralement moins actifs et plus vêtus que les enfants, ils sont moins exposés au risque d'infection.

D'autre part, la syphilis est rare dans les régions où le pian sévit à l'état endémique, fait qui suggère l'existence d'une certaine immunité croisée entre les deux maladies. Cette immunité croisée est particulièrement

syphilis and in those cases of yaws where the active period or the latency is of long duration. This is due to the fact that the processes activating the immunizing mechanism develop much faster in syphilis than in yaws.

Tables are also given showing the age-distribution of infectious yaws lesions in two areas in Jamaica, the reductions in attack-rates after treatment, and the percentages and types of relapses after treatment with neoarsphenamine and bismuth salicylate. These show that relapses after such treatment are about 14 % after one year and 25 % after two years, and that treated infectious cases give a higher percentage of infectious relapses than treated latent or non-infectious cases.

Since the child population is more susceptible to yaws than the adult and since there is little immunity to a second infection immediately after treatment of the disease in its early stage, the author feels that an immunological approach is worth considering. He is working on an active and passive method of immunization, gamma globulin from the blood of adults who have had yaws being injected into actively diseased children. This globulin will be given as a first injection in order to stimulate immunity; some time later the patient will be cured with penicillin. It is hoped that such treatment may produce a cross-immunity to syphilis and prevent reinfection or relapse.

Finally, the author gives two objectives to be observed in eliminating yaws :

(1) adequate treatment, not merely to render cases non-infectious but rather to cure cases completely and thus avoid relapses, and

(2) follow-up and consolidation of mass-treatment programmes to treat any relapsing cases.

nette dans la syphilis et dans les formes de pian dont la phase évolutive ou la phase de latence est de longue durée. La raison est que le processus d'immunisation est beaucoup plus rapide dans le cas de la syphilis que dans celui du pian.

L'étude s'accompagne de tableaux indiquant par groupes d'âge la fréquence des lésions pianiques contagieuses dans deux régions de la Jamaïque, la diminution de fréquence des attaques après traitement, et les pourcentages et la nature des rechutes après traitement par la néoarsphénamine et le salicylate de bismuth. Ces chiffres montrent d'une part que la fréquence des rechutes après ce traitement est d'environ 14 % après un an et d'environ 25 % après deux ans. Il font également ressortir que le pourcentage des rechutes de pian contagieux est plus élevé chez les malades traités qui avaient été atteints de pian contagieux que chez ceux qui avaient souffert de pian latent ou non contagieux.

Comme les enfants sont plus sujets au pian que les adultes et que le traitement de la maladie à sa phase précocée n'est suivi, dans l'immédiat, que d'une faible immunité, il serait utile d'envisager le problème du point de vue immunologique. L'auteur s'efforce de mettre au point une méthode d'immunisation active et passive qui consiste à injecter à des enfants souffrant de pian à la phase évolutive de la gamma globuline prélevée dans le sang d'adultes ayant contracté la maladie antérieurement. L'auteur commence par une injection de globuline afin de susciter l'immunité et, quelque temps après, administre de la pénicilline. Il espère que ce traitement sera susceptible d'engendrer une immunité croisée à l'égard de la syphilis et de prévenir les réinfections ou les rechutes.

L'auteur souligne enfin qu'il y a deux principes essentiels à observer dans la lutte contre le pian :

1) il faut appliquer un traitement qui ne vise pas simplement à blanchir les malades, mais qui assure une guérison complète et évite les rechutes;

2) il faut exercer une surveillance post-thérapeutique et consolider les résultats des programmes de traitement de masse en soignant toutes les rechutes.

REFERENCES

1. Bloss, J. F. E. (1946) *Trans. R. Soc. trop. Med. Hyg.* **40**, 225
2. Carman, J. A. (1935) *Trans. R. Soc. trop. Med. Hyg.* **29**, 261
3. Castellani, A. & Chalmers, A. S. (1919) *Manual of tropical diseases*, 3rd ed. London
4. Chambers, H. D. (1937) *Trans. R. Soc. trop. Med. Hyg.* **31**, 245
5. Chambers, H. D. (1938) *Yaws (framboesia tropica)*, London
6. Charlouis, M. (1881) *Vjschr. f. Derm.* **8**, 431
7. Findlay, G. M. (1946) *Trans. R. Soc. trop. Med. Hyg.* **40**, 219
8. Hackett, C. J. (1946) *Trans. R. Soc. trop. Med. Hyg.* **40**, 206
9. Harrison, L. W. (1947) *Lancet*, **2**, 964
10. Hermans, E. H. (1931) *Acta leidsia*, **6**, 1
11. Hewer, T. F. (1946) *Trans. R. Soc. trop. Med. Hyg.* **40**, 224
12. Hudson, E. H. (1946) *Treponematoses*, New York
13. Jahnelt, F. & Lange, J. (1928) *Klin. Wschr.* **7**, 2133
14. Jolly, G. G. (1926) *Indian med. Gaz.* **61**, 581
15. Kumm, H. W. (1935) *Ann. trop. Med. Parasit.* **29**, 283
16. Kumm, H. W. (1935) *Trans. R. Soc. trop. Med. Hyg.* **29**, 265
17. Kumm, H. W. & Turner, T. B. (1936) *Amer. J. trop. Med.* **16**, 245
18. Kumm, H. W., Turner, T. B. & Peat, A. A. (1935) *Amer. J. trop. Med.* **15**, 209
19. Lopez Rizal, L. & Sellards, A. W. (1926) *Philipp. J. Sci.* **30**, 497
20. McKenzie, A. (1924) *Lancet*, **2**, 1280
21. Mattlet, G. (1933) *Ann. Soc. belge Méd. trop.* **13**, 13
22. Maxwell, J. S. (1927) *J. trop. Med. Hyg.* **30**, 294
23. Moss, W. L. & Bigelow, G. H. (1922) *Johns Hopk. Hosp. Bull.* **33**, 43
24. Nitsen, R. van (1944) *Mém. Inst. colon. belge Sci. nat.* **13**, no. 1
25. Oho, O. (1922) In : *Far Eastern Association of Tropical Medicine, Transactions of the Fourth Congress . . . Weltevreden, Batavia 1921*, **2**, 138
26. Paulet, P. (1848) *Arch. gén. Méd.* **17**, 385
27. Powell, A. (1896) *Brit. med. J.* **8**, 457
28. Powell, A. (1923) *Proc. R. Soc. Med.* **16**, 15
29. Rae, A. M. W. (1951) *Brit. J. vener. Dis.* **27**, 118
30. Ramsay, G. C. (1925) *J. trop. Med. Hyg.* **28**, 85
31. Reynolds, F. W., Guthe, T. & Samame, G. (1951) *J. vener. Dis. Inform.* **32**, 236
32. Robertson, A. (1908) *J. trop. Med. Hyg.* **11**, 213
33. Saunders, G. M., Chambers, H. D. & Rerrie, J. I. (1936) *Annual report of the Jamaica Yaws Commission for 1936*, Kingston, Jamaica
34. Saunders, G. M., Kumm, H. W. & Rerrie, J. I. (1936) *Amer. J. Hyg.* **23**, 558
35. Schaar, P. J. van der (1933) *Geneesk. Tijdschr. Ned.-Ind.* **73**, 1138
36. Schöbl, O. (1928) *Philipp. J. Sci.* **35**, 290
37. Scott, C. J. (1933) *Proc. Transv. Mine med. Offrs' Ass.* **12**, 41
38. Silva Araujo, O. da (1928) *Bull. Soc. Path. exot.* **21**, 387
39. Spittel, R. L. (1922) *J. Ceylon Br. Brit. Med. Ass.* **2**, 1
40. Thomas, E. W. (1949) *Syphilis : its course and management*, New York
41. Thomson, J. G. & Lamborn, W. A. (1934) *Brit. med. J.* **2**, 506
42. Turner, T. B. (1936) *Amer. J. Hyg.* **23**, 431
43. Turner, T. B. & Saunders, G. M. (1935) *Amer. J. Hyg.* **21**, 483
44. Yawuyama, K. (1928) *Philipp. J. Sci.* **35**, 333